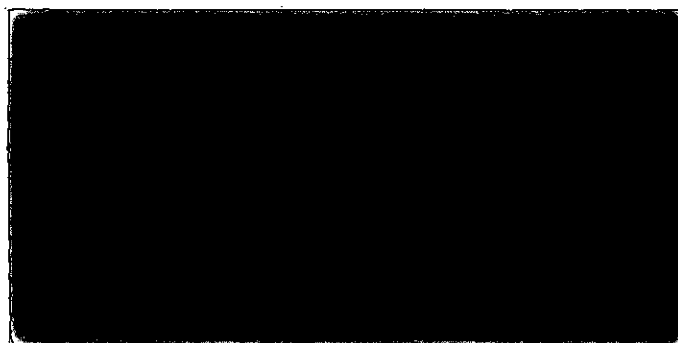
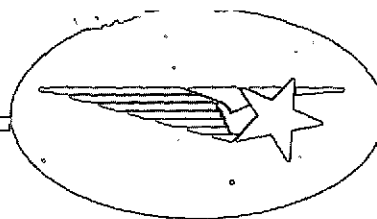


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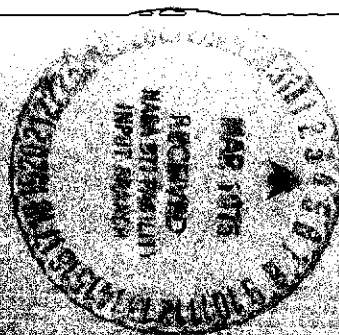


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22 August 1974

A MULTI-SATELLITE STUDY OF THE NATURE  
OF WAVELIKE STRUCTURES IN THE  
MAGNETOSPHERIC PLASMA

Contract NASw 2551

FINAL REPORT

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## FINAL REPORT

### A MULTI-SATELLITE STUDY OF THE NATURE OF WAVELIKE STRUCTURES IN THE MAGNETOSPHERIC PLASMA

Contract NASw 2551

This was a program for the analysis of data from the Lockheed light ion mass spectrometer experiment on Ogo 5.

Under this program an intercomparison was made of the wavelike structures in the data from the light ion mass spectrometer and the UCLA fluxgate magnetometer on Ogo 5. The wavelike structures appear simultaneously in the data from both experiments. The waves contain both transverse and compressional modes and exhibit periods of 100-200 seconds. The waves are usually observed outside the plasmopause and are located primarily on the dayside of the magnetosphere. Waves with similar characteristics have been observed previously by Cummings on ATS-1. One possible cause of the apparent density fluctuation is a velocity modulation of the thermal plasma which causes the particles to drift into and out of the ion spectrometer.

This research was conducted as a cooperative project by Dr. C. R. Chappell of Lockheed and Dr. C. T. Russell of UCLA. Dr. Chappell was at Lockheed during the course of most of the program, but has since moved to the Marshall Space Flight Center in Huntsville, Alabama. A paper on these results is being prepared by him and Dr. Russell of UCLA at this time and will be submitted to the Journal of Geophysical Research. Preliminary results were presented at the 55th Annual Meeting of the American Geophysical Union\*.

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\* "Correlated Ogo 5 Measurements of Wavelike Structures in the Magnetospheric Plasma," C. R. Chappell and C. T. Russell, Trans. Am. Geophys. U., 55, 296, 1974.

As indicated in our last quarterly report, the small amount of resources remaining in this contract were utilized to finish up a related study of the Ogo 5 cold plasma data conducted by Dr. K. K. Harris. This project involved a comparison of the light ion mass spectrometer values for plasma density in the trough with plasma density values derived from the TRW plasma-wave experiment on Ogo 5 in order to verify that vehicle potentials or other effects were not affecting the direct measurements of the plasma density in this important region. Dr. F. Scarf of TRW cooperated in this study. The results of this analysis were included in a paper which has been accepted for publication by the Journal of Geophysical Research and is included as Appendix A.

A P P E N D I X    A

THE MEASUREMENT OF COLD ION DENSITIES  
IN THE PLASMA TROUGH

K. K. Harris

March 1974  
(Revised June 1974)

A-1

## THE MEASUREMENT OF COLD ION DENSITIES IN THE PLASMA TROUGH

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## ABSTRACT

The cold ion density in the plasma trough region is an important fundamental parameter in the currently proposed mechanisms to describe magnetospheric dynamics. Direct in-situ measurements of the cold ion density are generally difficult owing to uncertainties in vehicle potentials and ion temperatures. It is shown that the Light Ion Mass Spectrometer (LIMS) data fromOGO-5 was very successful in acquiring these data and that vehicle potentials appear not to have been a prohibitive factor. The cold ion plasma trough data show a great deal of variability indicating a strong dependence on the state of the convection electric field; consequently, average values of cold ion densities in the plasma trough may be significantly different from the actual time-dependent values. The local time plot of plasma trough densities at  $L = 7$  for data acquired over a one-year period shows the anticipated increase in cold ion density during the daytime and the expected decrease in cold ion density during dusk and early nighttime. This pattern is closely predicted by magnetospheric convection models. An unusual feature of these data is, however, a substantial dip in the cold ion density near local noon. The ionospheric filling of the plasma trough, as deduced from the LIMS data, also shows excellent qualitative agreement with that which would be expected from magnetospheric convection models. The average ionospheric  $H^+$  ion flux flowing into the trough region from the base of the flux tube as calculated from these data is found to be approximately  $1 \times 10^8$  ions/cm<sup>2</sup> sec at 1000 km altitude. This average  $H^+$  ion flux is consistent with ionospherically originated  $H^+$  fluxes predicted by the theory of the polar wind.

# INTRODUCTION

A complete experimental picture of the distribution of cold plasma within the magnetosphere is beginning to emerge. Ground-based whistler studies have long been used to obtain large scale features of the plasmasphere [Carpenter, 1963, 1966, 1970; Park and Carpenter, 1970], but it was not until the direct in-situ measurements were made from satellites that the complexity of the cold plasma distribution within the magnetosphere was realized. Recent satellite measurements, most notably the OGO series and in particular the OGO-5 satellite, have given a very detailed picture of the plasmasphere region of the magnetosphere [Harris et al., 1970; Chappell et al., 1970a, 1970b, 1971; Taylor et al., 1965, 1968, 1970, 1971]. Only very recently has it been recognized that the cold plasma is a fundamental parameter in determining some of the characteristics and the dynamics of the magnetosphere [Cornwall et al., 1970, 1971; Eather and Carovillano, 1970; Lyons et al., 1972].

The data that will be discussed in this paper were obtained from the Light Ion Mass Spectrometer (LIMS) carried aboard the OGO-5 spacecraft. The LIMS instrument had extremely high sensitivity thus enabling it to acquire data with precision in the low ion density regions of the magnetosphere. The data from this instrument have been used extensively to assist in developing the understanding of the plasmasphere, the high ion density region of the magnetosphere [Harris et al., 1970; Chappell et al., 1970a, 1970b, 1971]. The details of the operation of the instrument are contained in earlier publications [Harris and Sharp, 1969; Harris et al., 1970a] and will not be a

repeated here except as they pertain to the uniqueness associated with the plasma trough region.

The data acquired from the LIMS spanned a period from March 1968 until June 1969. Thus, more than one complete year of data was obtained. The data presented here will be confined to the first operational year of the instrument. Essentially uniform coverage in local time is thereby obtained.

#### PLASMA TROUGH DEFINITION

The plasma trough is that region of the magnetosphere that lies immediately outside of the plasmasphere and extends in general to the magnetopause. The inner boundary of the plasma trough is marked by the plasmapause, the terminus of the plasmasphere. Unfortunately, the location of the plasmapause is not always precise. Most commonly the plasmapause is defined as the steep gradient in the cold plasma concentration as one moves radially outward from the earth. But unfortunately a steep gradient does not always exist. The data on April 20 inbound and June 21 inbound of Figure 1 indicate that under certain magnetospheric conditions it is possible to have a very gradual concentration gradient for the cold plasma from the ionosphere out to the magnetopause. In this situation one is hard pressed to identify the plasmapause by the requirement of a steep gradient. A further complication occurs when more than one steep gradient exists as seen in the June 19 inbound pass of Figure 1. Which gradient is then ascribed to be the plasmapause? And, consequently, where is the plasma trough region?



A more precise definition of the plasmopause location is provided by the magnetospheric convection model [see review by Axford, 1969]. In this model, the plasmopause may be defined as the boundary between the magnetic flux tubes which corotate with the earth and remain continuously closed and the flux tubes which are convected to the magnetopause. This model is illustrated in Figure 2 where the paths of the circulating magnetic flux tubes in the equatorial plane are shown. The "dashed" curves are the paths of flux tubes which circulate about the earth, but move sunward to the boundary of the magnetopause. At the magnetopause the field lines merge with the interplanetary magnetic field and are then convected to the tail region of the magnetosphere. In this process the cold plasma in the flux tube is lost to the plasmasphere. Eventually the field lines become reconnected in the tail region and once again begin their recirculation. The dotted paths represent paths of flux tubes which do not move sunward to the boundary of the magnetosphere but continue to corotate with the earth. The portion of the inner solid curve which closes upon itself represents the boundary between the corotating and the non-corotating flux tubes and consequently is the plasmopause boundary. Although this definition of the plasmopause is more precise, its utility is often difficult because the location of this boundary depends on the strength of the convection electric field which is subject to frequent change.

In this paper we shall adopt the convention that each steep gradient beyond  $L = 2.5$  represents the plasmopause, or a former plasmopause. In this context a "steep density gradient" refers to an ion density change of a factor of two in a distance of  $0.2L$ . The steep density gradient located at the greatest radial distance will then be assumed to be the most recent

plasmopause. The region of the plasma trough will then be defined generally as that region immediately outside the steep plasma gradient of the greatest extremity. We shall also wish to describe the region between two or more steep plasma gradients, for this region represents a former plasma trough region that has begun to refill with cold plasma from the ionosphere. Upon sufficient filling the interior steep plasma gradient gradually disappears and what formerly was a trough region becomes a part of the main body of the plasma, i.e., the plasmasphere. Thus the plasma trough region is transitory in nature and has been shown to depend directly upon the convection electric field present, which in turn is coupled to the magnetic activity [Chappell et al., 1971].

#### VALIDITY OF THE LOW DENSITY ION MEASUREMENTS

A major contributing factor to the paucity of very low cold ion density measurements in the magnetosphere is adequate sensitivity in the measuring instrument. With the development of the LIMS instrument, with its extremely high sensitivity, this problem has been overcome. Nevertheless some problems and uncertainties remain. It has been pointed out by Parker and Whipple [1970] that ion sheath structure, ion angle of attack, draw-in potentials, and vehicle potentials play an important part in correctly interpreting direct in-situ plasma measurements. They have shown that under conditions of attractive vehicle potentials and draw-in potentials, large Debye lengths and large acceptance angles for an instrument, it is possible to overestimate the ambient cold  $H^+$  density by a considerable amount. This overestimate, however,

is strongly dependent upon the angle of attack, and is minimized for an angle of attack of zero degrees. In the LIMS instrument no attractive draw-in potentials were used in collecting the data and the angle of attack of the ions was in the absence of ion drift essentially zero degrees. Thus, the effects suggested by Parker and Whipple have been minimized.

Of considerable more concern than the effects caused by an attractive vehicle potential on these data is the effect of a repulsive vehicle potential. A positive vehicle potential of sufficient magnitude would repel cold protons and keep them from entering the LIMS so that rather than having an overestimate of the cold ion density in the plasma trough, a substantial underestimate would result. Compounding this problem is the fact that the plasma trough region is the region where vehicle potentials are most likely to become positive. For in the plasma trough region, where the ion and electron density is low, the photo emission from the surface of the spacecraft has its greatest relative effect. Thus, the possibility must be considered that photo emission has on occasion driven the spacecraft potential positive and thereby caused the LIMS instrument to underestimate the ambient cold plasma in the plasma trough.

Upon analyzing the great quantity of data from the LIMS instrument, there is no indication in the data that might suggest that a repulsive vehicle potential is limiting the current to the instrument. An internal check on the effects of a repulsive vehicle potential is available owing to the difference in the relative kinetic energy of the  $\text{He}^+$  ions and the  $\text{H}^+$  ions with respect to the moving vehicle. In the frame of the moving vehicle,  $\text{He}^+$  ions have typically  $1/3$  eV more energy than  $\text{H}^+$  ions in the plasma trough

region. Thus, as the vehicle potential progresses from a negative potential toward a positive potential one could expect a significantly different response of the instrument with respect to the two ions. Such differences are not observed; the  $\text{He}^+$  ion and the  $\text{H}^+$  ion distributions give no indication of having been retarded at different rates by a changing vehicle potential.

In further support of the position that the plasma trough ion density measurements are indeed correct are the results from independent calculations of plasma density from wave measurements from OGO-5. Figure 3 is a comparison of cold ion density measurements from the LIMS (indicated by "H" in Figure 3) and electron density calculation from electrostatic electron-cyclotron harmonic-wave emissions [Oya, 1972] detected at the same time from the OGO-5 spacecraft by the TRW plasma wave experiment. These data correspond to two separate passes, one occurring inbound on August 15, 1968 at about  $L = 7.5$  and the other inbound on September 5, 1968 at about  $L = 7.3$ . The agreement between the electron density calculations and the cold ion density in the range from 0.1 to 0.4 ions/cm<sup>3</sup> is in general very good. Also, calculations of electron density from Chorus measurements by the TRW plasma-wave experiment on OGO-5 have been obtained for the inbound pass of August 15, 1968 at about 0800 UT and  $L = 6.4$ . Results of these calculations give an electron density of 0.2 ions/cm<sup>3</sup> [F. Scarf, private communication]. These results are found to be in very good agreement with the cold ion densities measured simultaneously by the LIMS.

## RESULTS OF THE PLASMA TROUGH MEASUREMENTS

In an attempt to describe the typical cold plasma density in the plasma trough, a plot is made (Figure 4) of the cold ion density at  $L = 7$  as a function of local time. These data are for all orbits obtained during the first year of operation of the LIMS instrument. The location of  $L = 7$  is almost always outside the plasmopause for all local times. For this reason  $L = 7$  was chosen as the location to represent the character of the plasma trough region. Under extremely quiet magnetic conditions for prolonged periods, however, it is possible to have the plasmopause out beyond the  $L = 7$  location. The data presented in Figure 4 are for the cases in which a steep ion gradient is observed "inside" the  $L = 7$  location. This criterion excluded only a very few data points.

The data points in Figure 4 are accumulated for both the inbound and the outbound crossing of the  $L = 7$  location for one complete year of OGO-5 operation. As a result, the complete local time region is covered by both the inbound set of data and the outbound set of data. Since the difference in local time for the inbound and the outbound crossings at  $L = 7$  is from nine to thirteen hours, the accumulation of data points in any given local time sector is then in effect from two different seasons of the year.

It should be noted that near Summer or Winter Solstice there are some longitudes for which at least one of the ends of the  $L = 7$  flux tube at ionospheric altitudes is illuminated at all local times. Under these conditions the filling of the  $L = 7$  flux tube is continuous. The data points representing continuous filling will be few in number, however, since the data in any local time sector are averaged over more than one

season of the year and the longitudes at the  $L = 7$  crossing occur randomly. Although the data points representing continuous filling will contribute to the scatter in the data they will not seriously affect the general data trends.

The scatter in the data in Figure 4 is also the result of averaging over magnetic field conditions for the one complete year of data. The effects of magnetic storms and periods of magnetic inactivity are included in the data and at present no attempt has been made to isolate these effects.

The general features of the data may be characterized as filling of the  $L = 7$  flux tube during the daytime hours, with a loss in the plasma concentration in the early evening hours, followed by a relatively constant concentration in the local time region near midnight. The filling of the flux tube appears most dramatic in the period from 02:00 hours to 09:00 hours. This appearance is, however, somewhat misleading and is exaggerated by the nature of the semi-logarithmic plot. The actual filling rate is expected to be a linear function of the time in which the ionosphere at the base of the  $L = 7$  flux tube is illuminated. The maximum ion density in the  $L = 7$  flux tube generally occurs in the local time region near 15:00 hours. At local times later than 15:00 hours the ion density in the  $L = 7$  flux tube shows a rapid decrease with local time.

The local time distribution of the cold plasma in the plasma trough is in good qualitative agreement with the magnetospheric convection model. For the local time period from 02:00 hours to 15:00 hours the E-region of the ionosphere at the base of the  $L = 7$  flux tube is generally illuminated

by the sun. The ionization produced in the ionosphere may then flow up the flux tube into the region of the plasma trough.

During this period the convection processes generally cause a corotation-like motion (see Figure 2) and the plasma is retained in the plasma trough. The filling of the trough at  $L = 7$  should proceed at essentially a constant rate and, as a result, the cold ion density should exhibit a linear dependence on local time. These data have, therefore, been fitted to a linear function by the least-squares technique. Since the ion density data ranges over two decades, the least square fit was weighted by the inverse value of the density at each point. The result of the least-square fitting is shown by the solid line drawn through the data in Figure 4, extending from 02:00 hours local time to 15:30 hours local time. Assuming that ions entering the flux tube are uniformly distributed throughout the flux tube and the the filling rate is a linear function of time, then the ion density within the flux tube is given by

$$n = \frac{F A t}{V}$$

where  $n$  = cold ion density,  $F$  = cold ion flux at the base of the flux tube,  $V$  = volume of the flux tube, and  $t$  = filling time. The calculated value of the cold ion flux at 1000 cm altitude obtained from the slope of the linear fit is  $1.1 \times 10^8$  ions/cm<sup>2</sup>/sec. This value for the upward ion flux at 1000 km is found to be in good agreement with the value predicted by the polar wind theory [Banks et al., 1971].

Inspection of the data in Figure 5 reveals an unexpected occurrence in the 10:00 hours to 13:00 hours local time region. The majority of the data points in this local time region fall below the linearly fitted curve by slightly more than one standard deviation,  $\sigma$ . The data points were included in the linear fit analysis even though the data points in this local time region do have the appearance of clustering about a density value that is significantly lower than would be predicted by the linear filling model. At the present time no explanation is available for describing the consistently low ion densities found at  $L = 7$  in the near-noon local time period. It has been determined, however, that these data do not have any specific correlation with either the magnetic latitude at which the density measurement is made or the general conditions of magnetic activity as measured by  $K_p$ .

The data indicate that the cold plasma density at the  $L = 7$  location is significantly reduced as a function of local time for local times greater than about 15:30 hours and is most pronounced near 18:00 hours. The reason for this fall-off in plasma density will be discussed below. The negative slope in the data continues until about 21:00 hours local time. At this local time, about 22:00 hours, the minimum in the trough concentration is reached. This minimum value is in the neighborhood of  $0.1 \text{ ions/cm}^3$ . The data then indicate a flat region for the plasma density through the midnight region and on until about 02:00 hours where once again the filling process begins anew. The flat concentration in the midnight region indicates that very little, if any, filling takes place in this time sector which is expected since the ionosphere is in general not illuminated.

The local time region beyond 24:00 hours on the extreme right-hand side of Figure 4 is a duplication of data from the extreme left-hand side



of the figure and is shown for continuity and clarity. The plasma density distribution as a function of local time presented in these data is found to be in very good qualitative agreement with that predicted by the magnetospheric convection model. Referring back to Figure 2, one observes that the convection model predicts an accumulation of plasma in the plasma trough with increasing local time in the dayside owing to upward flow from the ionosphere. In Figure 2 the solid line that closes upon itself and has been used to define the plasmapause has an extension into the afternoon sector of the magnetosphere. This line forms the boundary between convecting flux tubes that circulate through the dayside sectors and flux tubes that convect from the nighttime sector through the evening and dusk sectors. The flux tubes that lie on the noon side of the boundary have circulated through the daytime sectors and have been filled with plasma flowing up the flux tube from the ionosphere for the better part of the day. The flux tubes that lie on the dusk side of the boundary have migrated from the nighttime regions and as a result are filled with plasma from the ionosphere only as they convect through the dusk region. As a result, the flux tubes on the dusk side of the boundary have considerably less plasma in them owing to their much shorter filling periods. Furthermore, the flux tubes on the dusk side of the boundary will show a decrease in plasma density with local time because of their progressively abbreviated filling periods. Thus the maximum plasma trough density will be obtained at the convection boundary. This boundary typically lies in the neighborhood of 15:00 hours local time. As the boundary is crossed the plasma trough density will then show a rapid decrease with local time until the minimum value is reached. This should occur at some local time after 18:00 hours. The plasma trough density should then remain constant with local time until the ionosphere filling process begins again.

# A SPECIFIC CASE OF FILLING THE PLASMA TROUGH

It is difficult to monitor the detailed plasma trough filling process from the OGO-5 data because the time scales for change in the convection electric field (as monitored by magnetic activity) are short compared to the OGO-5 orbital period of 2-1/2 days. Nevertheless in the time period from late in the day on Sept. 23, 1968 to Sept. 28, 1968, the magnetic activity was unusually stable and quiet. This quiet period followed a magnetically disturbed period with the 3-hour Kp generally greater than four for the early part of the day on September 23, 1968. During this time period, three passes of the OGO-5 vehicle traversed the magnetosphere and in each, high-quality data from the LIMS instrument were obtained.

The first set of data, on September 23, 1968, was obtained shortly after the convection electric field had caused the plasmopause to move inward and the plasma in the trough region to be exhausted to the magnetosphere. The second set of data occurred after 2-1/2 days of plasma filling in the trough region. The 3-hour Kp index was generally less than one for this period and, as a result, the location of the plasmopause was generally greater than  $L = 7$ . Thus, the plasma in the trough region was the accumulation of more than one day's filling from the ionosphere. The third set of data occurred after a further 2-1/2 days of plasma filling in the trough region.

The 3-hour Kp index is shown in the histogram in Figure 5 for the period September 23-28, 1968. Plotted alongside of the histogram are the results of the LIMS data for the three outbound passes in this period. The plasmopause is observed to be at about  $L = 3.8$  in the September 23 and 26 passes. The plasma trough concentration at say  $L = 7$  is found to be between 2 and 3 ions per  $\text{cm}^3$ . At  $L = 7$  on the outbound pass of September 26, the ion density is

found to be 8-10 ions per  $\text{cm}^3$ . This represents about two days of filling for this flux tube. The ion concentration at  $L = 7$  on the September 28 pass after almost five days of filling is about 30 ions per  $\text{cm}^3$ . The former plasmopause of  $L = 3.8$  has now disappeared and the former trough concentration has merged with the main body of the plasmasphere. In each case the distribution of cold plasma in the trough region follows very closely a  $R^{-4}$  dependence [Chappell et al., 1970b].

There is good qualitative agreement of the LIMS data for these three consecutive passes with the plasma trough filling model described above. To investigate the agreement quantitatively requires a number of assumptions: 1) that filling takes place at a given rate and only during the time when the end of the flux tube resides in the illuminated ionosphere; 2) that no mechanisms are operative which would cause a loss of plasma from the flux tube; and 3) that exactly 24 hours are required for a flux tube to corotate around the earth. Utilizing these assumptions the average upward ion flux at the 1000-km level was calculated to be  $4.2 \times 10^7$ ,  $2.9 \times 10^7$ , and  $1.0 \times 10^8$  ions/ $\text{cm}^2/\text{sec}$  for the September 23, September 26, and September 28 passes, respectively.

These calculated average flux rates are somewhat lower than the average flux of  $1.0 \times 10^8$  ions/ $\text{cm}^2/\text{sec}$  at  $L = 7$  obtained from the data in Figure 4. It is rather likely that these calculated average fluxes are in some cases lower than the polar wind flux because of the assumption that no plasma escaped. Toward the end of September 24, 1968 the three-hour  $K_p$  index reached a value of greater than two. It is possible that part of the plasma in the flux tube was "dumped" at that time by the convection process. It is also quite probable that small localized convection events could take place

that could drain away plasma from the flux tube. Either of these effects would cause the calculated average flux to be lower than the true average value.

#### SUMMARY

The density of the cold plasma in the magnetosphere is an important fundamental parameter in determining some of the characteristics and dynamics of the magnetosphere. Direct in-situ ion density measurements in the plasma trough are difficult to make owing to uncertainties in the vehicle potential and the ion temperatures. The Light Ion Mass Spectrometer (LIMS) on OGO-5 has given good results for ion densities in the plasma trough region. No noticeable effects of vehicle potentials are present in these data. If the condition of a positive vehicle potential in the plasma trough region existed, then it appears that the thermal energy of the ions was sufficient to surmount this barrier. Comparison of the plasma trough densities with independent plasma wave results have been shown to be in good agreement with the LIMS data. The general results of the measured plasma density in the plasma trough are in agreement with the expected characteristics based upon the magnetospheric convection models. The filling rate of the  $L = 7$  flux tube in the plasma trough with thermal plasma from the ionosphere has been calculated from these data and is found to be on the order of  $1 \times 10^8$  ions/cm<sup>2</sup>/sec at 1000 km, in good agreement with the flux expected from polar wind theory.

# ACKNOWLEDGMENTS

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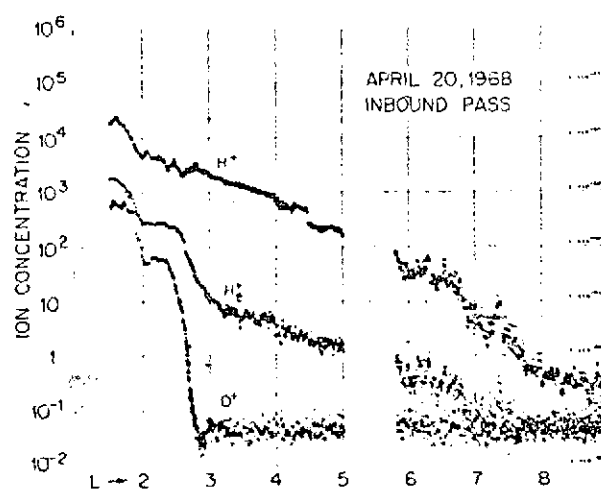
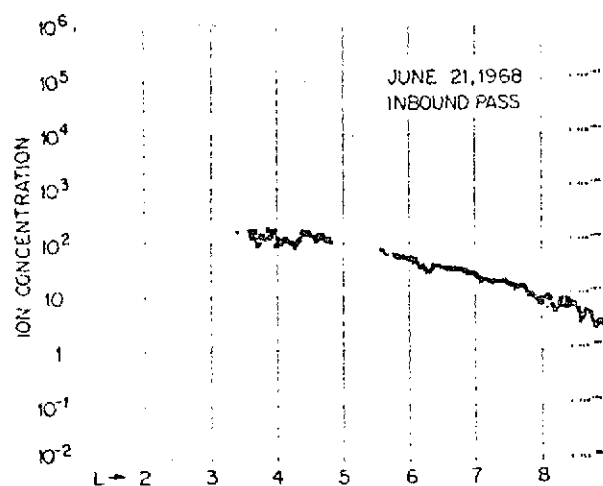
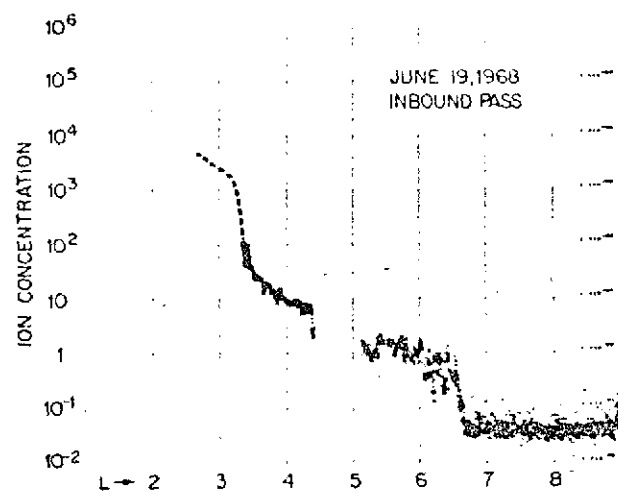
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Taylor, H. A., Jr., J. M. Grebowsky, and W. J. Walsh, Structured variations of the plasmopause: evidence of a corotating plasma tail, J. Geophys. Res., 76, 6808, 1971.



FIGURE CAPTIONS

- FIGURE 1       Examples of the variation of the cold plasma distribution in the magnetosphere.
- FIGURE 2       A convection model of the magnetosphere [Kavanagh et al., 1968]
- FIGURE 3       Comparison of ion density measurements from the LIMS (H's) and calculations of the electron density from electrostatic electron cyclotron harmonic-wave emissions [Oya, 1972].
- FIGURE 4       Ion density measurements in the plasma trough at  $L = 7$  for ever one complete year of LIMS data; the least-square fit between 02:00 and 15:00 hours LT is shown.
- FIGURE 5       An example of plasma filling in the plasma trough region.



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FIGURE 1

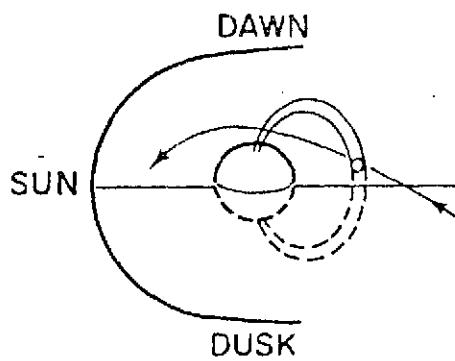
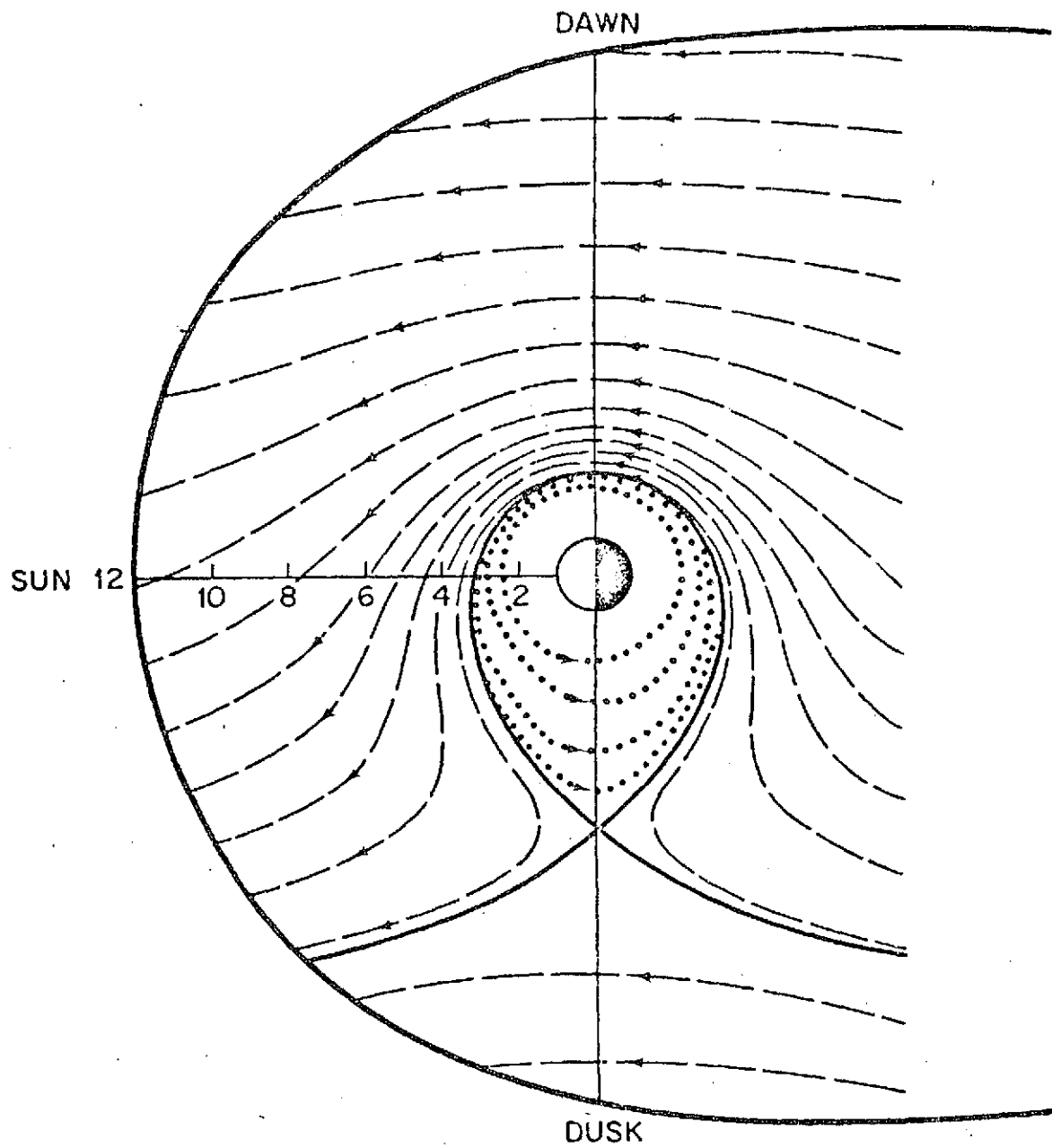


FIGURE 2



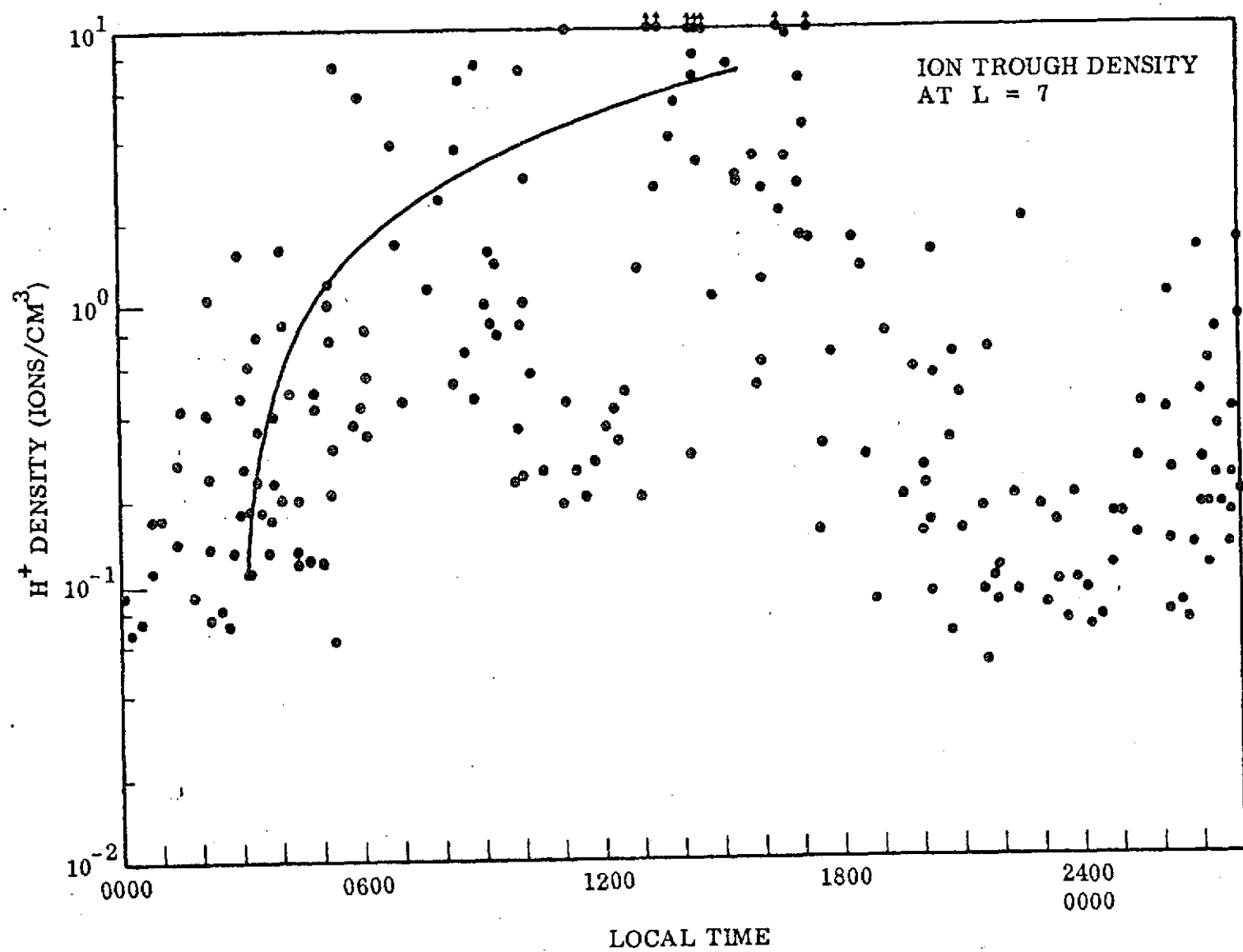
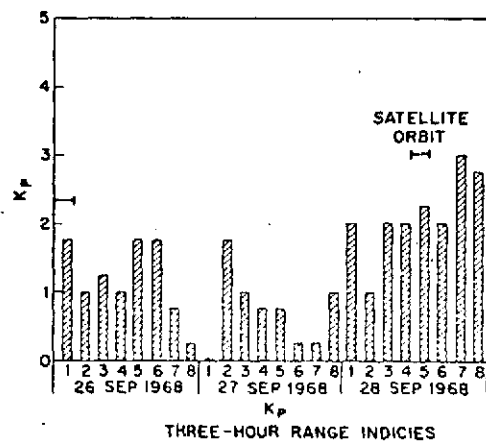
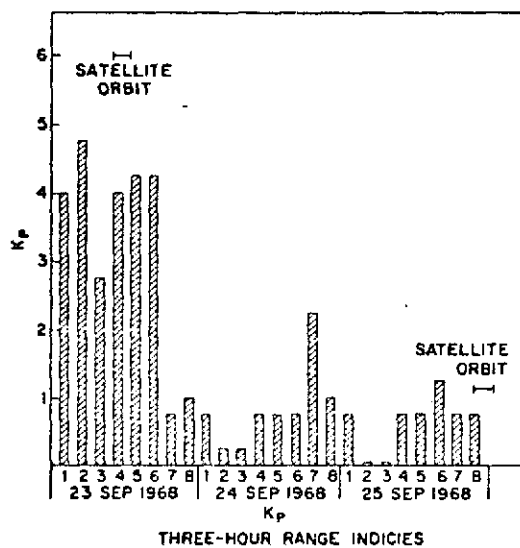
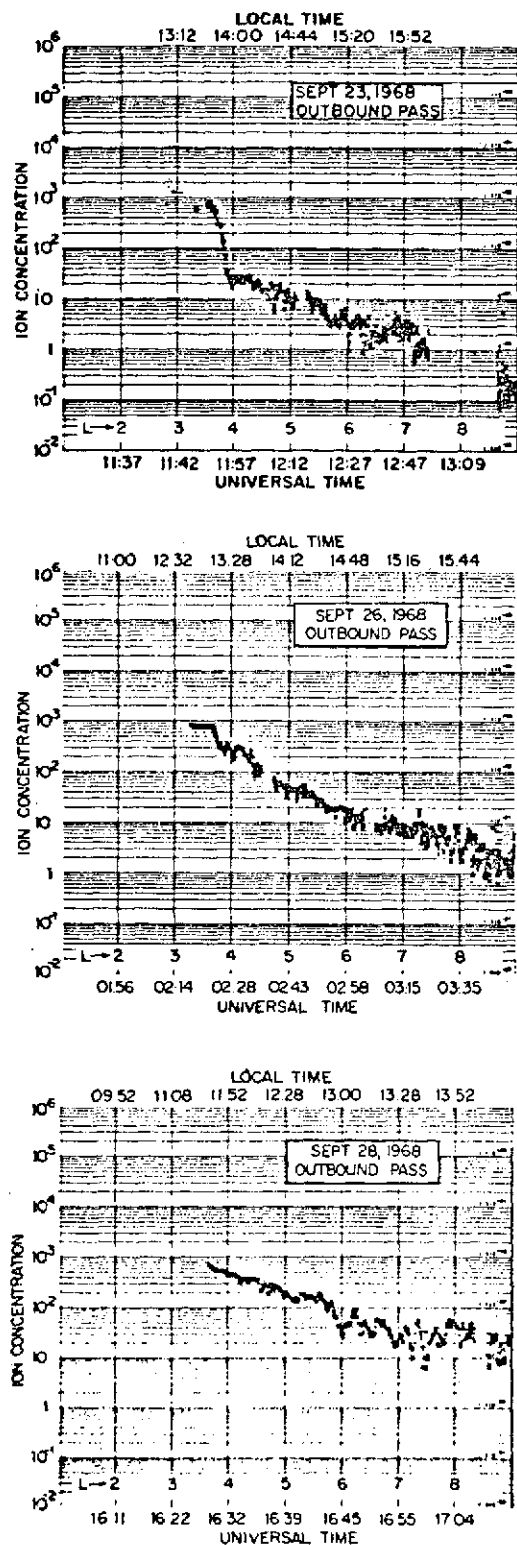


FIGURE 4



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FIGURE 5